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Electric Railway Traction

Remote Control of Substations

A PHASE of electric railway operation which is now coming to the fore is the control of two or more substations from a single point, the lead for which was given in this country by the installation on the Brighton extension of the Southern Railway, which regulates the operation of eighteen substations from the Three Bridges control house. Although in this case the substations are of the rectifier type there is no reason why the principle of remote-control should not be applied to rotary converter sets. On the Tyneside suburban lines of the L.N.E.R., the new rotary converter substation at Gosforth is remotely-controlled from Benton, and the similar plant now being erected at Earsdon Grange will be controlled from either Benton or Cullercoats. On a recent visit to the Lancashire electrified lines of the L.M.S.R., we were impressed by the simplicity and certainty of operation of the remote-control apparatus there installed. For instance, a circuit breaker tripped at Manchester (Victoria) substation was re-set from Radcliffe, seven miles away, inside a quarter of a minute. The starting up of one of the rectifier units takes but little longer. Switching in from Radcliffe, the operator there tries the a.c. side of the oil switch of the particular rectifier to be started, then the rectifier bulb, and on to the d.c. side of the rectifier. The rectifier bulb is then tested again, the ammeter readings noted, and the rectifier is in normal operation, the whole sequence taking approximately one minute. The ability to switch in or out, or re-set, any part of the converting plant from a central point, is a feature of great merit, and an appreciable extension of the practice may be anticipated.

Electric Traction in Britain

ALTHOUGH the electrified route mileage in Great Britain is only about 3 per cent. of the total railway route mileage, this figure is not unduly low if compared with those of countries in which conditions are more favourable to electric traction. Commencing with the City & South London Railway in 1890 and the Liverpool Overhead Railway in 1893-94, electrification did not make particularly rapid progress until the turn of the century. The first steam-worked line to change over to the then new form of traction was the Mersey Railway, in 1903, and this example was quickly followed by the Liverpool-Aintree-Southport lines of the Lancashire & Yorkshire Railway and the Tyneside suburban lines of the North Eastern Railway, with the result that by 1906 there were approximately 100 route miles of steam lines converted to electric operation, this including the Metropolitan lines electrified in 1905-6. Steady progress was made within the next decade, and, curiously enough, a fillip seemed to be given to electrification by the war, for the London & North Western Railway commenced electric operation between Willesden and Earls Court in 1914; the North Eastern Railway between Newport and Shildon in the same year; the Lancashire & Yorkshire Railway between Manchester and Bury, and the London & South Western Railway between Waterloo, Putney and Wimbledon in 1915; and the London & North Western Railway between Broad Street and Richmond in 1916. The tremendous development of the Southern Railway's electrified network in post-war years has tended to minimise the public appreciation of the extensions carried out by the Metropolitan and London & North Western Railways, and by the successor of the latter line, the L.M.S.R. At the present moment there are approximately 590 route and 1,585 track miles electrified in Great Britain, but by the summer of 1935, by which time it may be anticipated that the Southern Railway extensions to Sevenoaks, Hastings and Eastbourne will be in regular operation, the electrified route mileage will be at least 673 and the track mileage approximately 1,755.

Rectifiers Save Money

PROBABLY the greatest single advance which has been made in the science of electric traction within recent years is the perfecting and adoption of the mercury-arc rectifier, which, in its present state is ideally suited to the onerous conditions of railway service. Its efficiency is high over a very wide range of load—95 to 96 per cent. with three-quarters to full load and 92 to 94 per cent. on quarter load—which means a high "all-day" efficiency, even with a low load factor. Another characteristic is that the apparatus is entirely static, or almost so, which leads to simplified installation, operation, and maintenance. As far as already electrified lines are concerned, the simplified installation is not of great moment, as the rectifiers simply replace rotary converters in existing substations, but with new electrification schemes the adoption of rectifiers may lead to considerably lower initial cost on this score alone, for no special substation foundations or heavy cranes are necessary, and the substation itself can be in the form of either a brick building or a steel kiosk.

Perhaps of even greater moment from the traction point of view is the remarkable flexibility in output of modern rectifiers. Overloads may be thrown on instantly, and peak loads of up to 300 per cent. of the rated capacity can be withstood momentarily, and 200 per cent. carried for ten minutes or more. Moreover, rectifiers are flexible electrically, for not only are they suitable for operation on any voltage, phase, or periodicity, but the same equipment can be designed to operate on different supplies, a feature which is of considerable value in cases where various non-standard supplies will eventually be changed to a uniform type of current.

In so far as the electrical characteristics are concerned, there is little to choose between metal-clad and glass-bulb rectifiers, but the latter type is making headway in traction work by reason of its simplicity, the equipment being entirely static. There is, however, a field for both types, and in very large sizes only the steel tank type can meet the conditions at present. The maintenance troubles and operating difficulties of metal-clad units are largely confined to the vacuum and cooling water pumps and the possibility of back-firing. With the bulb type, the only possible source of failure in the rectifier is by a loss of vacuum in the bulb, and if the workmanship is good and the coefficients of expansion of the glass and connection the same, this risk is reduced to negligible proportions.

THIRTY YEARS OF RAILWAY ELECTRIFICATION

A prominent British railway electrical engineer traces the technical development of electrification in this country during the present century

By Lt.-Col. F. A. CORTEZ LEIGH, Electrical Engineer, L.M.S.R.

IT would be idle to deny that the electrification of steam railways in this country has not, during the period under review, progressed so quickly as the pioneers of railway electrification anticipated. It is probable that the general public, having in mind the proposals and recommendations of the Weir Committee, and with the example before them of the large amount of electrification carried out on the Southern Railway, to some extent share this view. It is proposed in this article briefly to relate what has been accomplished.

Before beginning our survey it may be noted that some of the conditions which in other countries have already lead to electrification of main line passenger and freight services are not present in this country. For example, in Italy and Switzerland the decision to electrify the entire railway system has, to a great extent, been reached on account of the desire to make use of water power resources and so to avoid the importation of coal. In France there was the desire to utilise water power resources which for their economical development involved coupling with railway electrification a scheme for the distribution of electricity for industrial and domestic purposes in the less intensely industrialised areas. On certain railways in the United States and on the Great Indian Peninsula Railway, the handling of heavy freight traffic over long and severe gradients had taxed the capabilities of the steam locomotive to the limit and provided conditions in which electrification offered the one satisfactory solution of the problem. None of these conditions exist in this country, and one must look elsewhere to find the reasons for the electrification which has already been done or for that which may yet be expected. What these reasons are will be evident from a consideration of the work which has been done, in which particular reference will be made to the electrification schemes undertaken by the London Midland & Scottish Railway and its predecessors, the London & North Western, Midland, and Lancashire & Yorkshire Railways.

The history of electrification in this country commences with the electrified tube railways in London, beginning with the City & South London line in 1890. At the beginning of the period under review the advantages of electric traction for services calling for a high schedule speed with frequent stops had been established by experience on this and other similar lines. It was found that, in addition to being the only satisfactory means of running underground railways, the new method of traction gave the main line railways an opportunity of increasing the efficiency of their suburban workings and of encouraging the growth of traffic by suburban developments.

The Lancashire & Yorkshire Railway early appreciated this, and it is now 30 years since the first trial trains were run on the Liverpool-Southport section of that company's line. The electrification was successful, and led to a considerable reduction in the timing of stopping trains between Liverpool and Southport, notwithstanding that additional stations had been built. The direct current system adopted was a natural development from existing tramway practice and permitted the use of batteries holding a reserve of power in substations. The conductor rail voltage chosen was 600 and a third rail only was used, the track rails being used for the return current. Later, when the service was increased, the return circuit was strengthened by a fourth rail laid between the running rails and bonded to them, but making no contact with the train. The power required for this line was generated in the company's own power station at Formby. Contemporaneously with the Liverpool-Southport electrification the North Eastern Railway electrified its Tyneside lines on the same system, viz., 600 volts d.c., with a third rail.

Shortly after this the controversy between single-phase and direct current became an important issue, and in 1908 the Midland Railway, in order to obtain some experience of the single-phase system of working, electrified a short section of line between Lancaster and Morecambe. at 6,600 volts. This was soon followed by the electrification of a portion of the suburban lines of the London, Brighton & South Coast Railway on the same system, which was discarded in favour of d.c. third-rail electrification after some 20 years of service, to conform

One of the first L.N.W.R. electric trains leaving Euston for Watford

Three-car train on the Southern Railway single-phase system (now converted to d.c.)

Modern six-coach train for the Euston-Watford service, L.M.S.R.

to the system adopted by the other two constituent companies of the Southern Railway.

The years immediately prior to the war were notable for the decision to provide electric services on the London & North Western and London & South Western Railways' London suburban lines. Both these schemes were undertaken on the d.c. system, the former using the third and fourth conductor rail system, thereby both avoiding any possibility of trouble with earth return currents and facilitating inter-running with the Underground railways. By this time certain difficulties, then inherent in the a.c. systems, had been fairly well established, and a desire was felt to secure the advantage of fewer substations by using the higher voltages, while retaining the d.c. series motor which had already an excellent reputation. It was in an attempt to secure these advantages that the Lancashire & Yorkshire Railway made the experimental electrification from Bury to Holcombe Brook in 1913, using an overhead contact wire at a voltage of 3,500 d.c. This development was no doubt somewhat ahead of its time and certain difficulties were encountered, and following the introduction of the Aspinall side-contact rail, it was decided to change this line over to side-contact third-rail at 1,200 volts, and to electrify between Manchester and Bury at the same time.

There have always been radical differences of opinion as to the most suitable method of electrification, and when the question of further conversion came to be considered at the conclusion of the war it was appreciated that a definite decision on the matter should be reached as soon as possible. As a result of this a committee, appointed to consider the problem in all its aspects, reported to the Minister of Transport in 1927 recommending that future electrification in this country should be on the direct current system with an overhead conductor at 1,500 volts (with a permissible 3,000 volts) or with a third rail at 750 volts. These recommendations are now incorporated in an Order of the Minister of Transport.

The Southern Railway has since converted its single-phase lines to the third-rail system, and has made great extensions of its electrified systems, culminating in the opening of an electric service to Brighton and Worthing in January, 1933. Of the other railways, the North Eastern Railway had electrified the heavy mineral line between Newport and Shildon on the 1,500 volt d.c. system with overhead contact wire in 1915, and in 1931 the Manchester, South Junction & Altrincham Railway (L.M.S.R. and L.N.E.R. Joint), having an intense suburban passenger service, was electrified on the same system, which was chosen largely on account of the importance of the line as a connecting link in the event of parts of the main line being electrified.

The present position is that whereas there is a strong feeling, supported by the recommendations of the Ministry of Transport Committee, that the 1,500-volt d.c. overhead conductor system should be used for eventual main-line electrification, the very extensive electrification of the Southern Railway appears to have committed that company to the low voltage third-rail system.

Differences in Power Supply

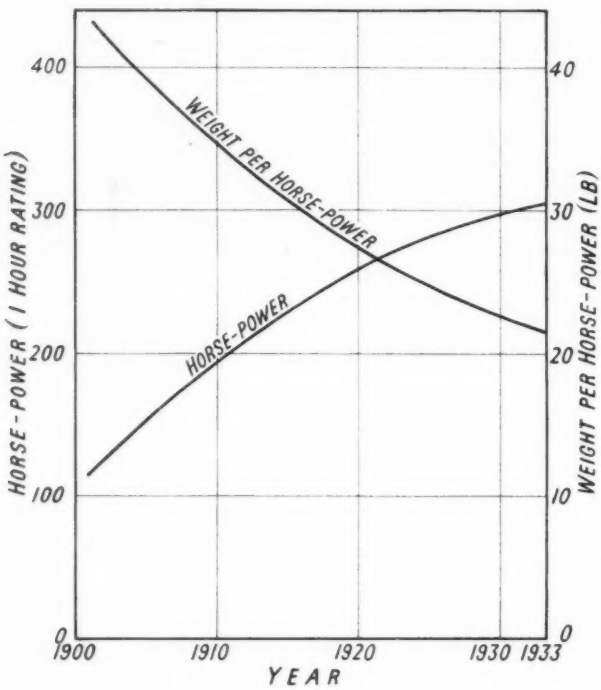
In considering the divergence of practice during the period under review, it will be noted that originally it was customary for a railway company to build its own generating station. In so doing it followed the general practice of the time, but with the special difference that in the early days, before rotary converters capable of dealing with traction overloads had been developed for use on 50-cycle supplies, it was essential to generate at a periodicity of 25 cycles or less. Another important consideration was that failure of supply could not be tolerated, and hence the railway preferred to have its generating station under its own control. Since converting plant, as now built, operates with entire satisfaction at 50 cycles, railway requirements can be met by the Grid, and although railway-owned power stations still exist, such as those of the L.M.S.R. at Formby and Stonebridge Park, it is unlikely that more will be built in the future, provided the Central Electricity Board is able to quote a tariff lower than that at which the privately-owned station could generate.

In the equipment of substations there has perhaps been more change than in any other department of electric traction. The earlier electrifications made use of the storage battery; by this means the shortcomings of the original converters in dealing with the heavy momentary loads inherent to the traction demand were overcome, and in the event of failure of the a.c. supply continuity of service was assured. In the later schemes, batteries are no longer economical as there is no difficulty in getting converting plant to handle the loads; on economic grounds, too, the cost of batteries is now prohibitive and, as has

been found on the Euston-Watford line, the expense of maintenance warrants their removal.

The mercury-arc rectifier has now practically superseded the rotary converter for a.c./d.c. conversion. The first mercury-arc rectifiers for traction service were of the steel tank type, and have given excellent service on the L.M.S.R. both in 600 and 1,500-volt service. Latterly, on economic and other grounds, a number of substations on the L.M.S.R. have been equipped with glass-bulb rectifiers, and as these are the first of their kind to be used on heavy traction duty, it is gratifying to note that so far, after upwards of a year in service, no regret is felt at the choice. Full particulars of the installations on the Liverpool & Southport and on the Manchester & Bury lines will be found in another article in this issue, and the simplicity of the equipments will be noted. In none of these cases was it possible to secure the full advantage of this type of unit, as the substations were in existence, but in future new work it is anticipated that considerable savings in substation cost will be possible by taking full advantage of the light weight of the units, and, further, the possibility of sectionalising the equipment to cut out a faulty bulb reduces the amount of spare plant necessary.

During the period under consideration, e.h.t. switchgear



Progress in traction motors used on the L.M.S.R. over a period of 30 years

has evolved in the direction of metal-clad units, as opposed to the stone or brick cellular construction of pre-war days, increased safety and economy being thereby attained. The use of high-speed d.c. breakers has become usual, not only for the protection of converters, but also on track feeders so as to disconnect any faulty section of track from the rest of the system quickly, and so limit the area affected by a fault. In a similar manner various forms of balanced feeder protection have been developed and have superseded the older overload and reverse current protection for new h.t. feeder networks in virtue of the more certain and rapid discrimination in cutting out a faulty feeder without affecting the whole supply system.

Another important development is the adoption of remote control whereby substation running costs are greatly reduced. Automatic substations began to appear about 1923. The first remotely controlled substation on the L.M.S.R. was brought into service at Plaistow in 1927 and operated on the same principle as an automatic telephone. When the electrification from Barking to Upminster with four substations came to be carried out, the opportunity was taken to control three of these from the fourth substation. Subsequently, as old plant on other electrified lines was replaced or augmented, three further single substations were redesigned for remote control.

Remote Control

Three different systems of remote control are now being used by the L.M.S.R., and all of them have given entire satisfaction. Although the subject is a very interesting one, it is not possible to give here a full description of the various systems, but details have been published from time to time in THE RAILWAY GAZETTE and in the Journal of the Institution of Electrical Engineers. It would not, however, be right to leave the subject without reference to the Southern Railway's electrification from London to Brighton with its eighteen substations, all controlled from a single control station, where provision is made for adding yet further controls as the electrification is extended.

Before leaving substations to pass on to other important developments, one might mention the now almost universal practice of installing outdoor transformers, and briefly note the effect of the developments in substation control and equipment so briefly described above on the relative economies of high and low voltage systems, not eliminating the difference in the cost of substations as between the two systems but reducing its relative importance.

The improvement in the characteristics of d.c. motors during the period under review is brought out by the accompanying illustration, which shows both the increase in horsepower of the motors in use on the L.M.S.R., and the reduction in the weight per horsepower. The form of the curves suggests that a region of stability has now been reached. Probably no further appreciable reduction in weight is possible with the materials at present available, and, on the other hand, the power now available is the maximum which can economically be employed in a two-motor bogie. The reduction in weight per h.p. has been due both to the better utilisation of material by improved design, and to the use of new materials and methods of construction, and it is gratifying to know that this reduction in weight has been accompanied by increased reliability and consequently by reduced maintenance costs. In this respect the use of roller bearings for traction motor armatures may be mentioned as not only avoiding the necessity for frequent lubrication, but also, more especially since the use of roller bearings has been extended to the axleboxes, reducing the current consumption.

The number of faults per 1,000 motor-car miles has fallen from 0·231 to 0·071 on one of the L.M.S.R. electrified lines during the past five years. Whilst admitting that this, like other statistics, is liable to be misleading, the extent of the decrease is so large as to give definite evidence of increased reliability. The improvement is no doubt due in some part to improvements in design of the kind mentioned above, but the larger part is due to improved methods of recording incipient faults so as to permit the improvement of the weaker parts of the equipment during inspection and thus avoid the developments of faults in service. On the latest stock on the Euston-Watford line, as already described in this Supplement for October 27 last, the control equipment has been assembled on frames which can easily be withdrawn as a whole from the equipment compartment.

THE DEVELOPMENT OF ELECTRIC TRACTION IN BRITAIN

A summary of the most important surface systems

Six-car train on Manchester, South Junction & Altrincham Railway

AT the beginning of the present century electric traction was still in an experimental state, and various systems were under trial or consideration. The year 1903 saw the beginnings of electric traction on the District Railway, but the great general conversion did not take place until 1905. In the earlier stages, the District advocated the present system, using direct current at 600 volts

Mersey Railway train at Birkenhead Park

with an outside conductor rail and centre-rail return. The Metropolitan Railway, on the other hand, is understood to have had leanings towards the three-phase system. The present universal system prevailing on the London underground lines was the result of a Board of Trade arbitration.

The District Railway had a precursor, in the form of the Mersey Railway between Liverpool and Birkenhead, which was the first British underground line to be converted from steam to electric traction. Open motor and trailer coaches have always been used on this line, and are generally similar to those adopted by the Metropolitan Railway on the realisation of its electrification projects in 1905-06. Direct current at 650 volts tension is used with side conductor rails and centre-rail return, and this system has worked well for 31 years over a route mileage of 4·8 and a track mileage of 11·9.

Early Lines in the Provinces

Two other pioneer lines may be found in Liverpool, the first of which is the Liverpool Overhead—the first electric overhead railway in the world. This line has been electrically operated since its inception in 1893-94. Direct current at 500 volts is used, with the third rail in the six-foot way and semi-open motor and trailer coaches normally operating as three-car sets. The line runs the length of the docks on a viaduct, and is double-track throughout the 6½ miles, of which the final southern stretch, from near Herculaneum Dock to Dingle is in a tunnel. Until a few years ago, this company also worked 2½ miles of tramway between Seaforth Sands and Great

Three-car electric train on Southern Railway suburban lines

Crosby. Originally 60 h.p. gearless motors were used on the set trains, but in 1901 these were superseded by 100 h.p. units of the nose-suspended type, which were replaced about 1922 with similar units of 75 h.p., on the decision being made to reduce the speed of the trains and make the service more frequent.

The other pioneer at Liverpool is the L.M.S.R. electric line to Southport, which was the first section of any trunk railway to be converted to electric working, for the electrification was carried out by the old Lancashire & Yorkshire Railway in 1904, and partial service was opened on March 22 of that year, a week before a partial service was commenced on the Tyneside lines of the N.E.R. The whole scheme of electrifying the line to Southport, Aintree and Ormskirk was completed by 1913, and the line, along with the Manchester-Bury section, is described in another part of this issue. In the Manchester division of the Lancashire & Yorkshire Railway system, the Bury-Holcombe Brook line was electrified in 1913, at 3,500 volts d.c. This was converted to 1,200 volts d.c. in 1916, after the opening of the Manchester-Bury line in 1915, and the system as a whole is unusual in employing a third rail for high-tension current.

Scarcely four months after the opening of the first section of the Liverpool-Southport line in 1904, the North Eastern Railway was working the whole of its North Tyneside suburban lines by electric traction, using 600-volts d.c. with third-rail contact, and multiple-unit trains. Part of the rolling stock is comparatively new, in spite of the age of the installation, owing to a fire in the car sheds at Walker Gate on August 11, 1918, when 34 vehicles were destroyed. Of the modern stock built after date, the motor-coaches each have two 140 b.h.p. motors mounted on the single motor bogie, geared to the axles at a ratio of 3·64 to 1. On Tyneside, as on the Liverpool-Southport section of the L.M.S.R., an electric parcels van service is run, but the design of the van incorporates two motor bogies instead of one, as in the passenger motor coaches. The Quayside goods line at Newcastle is operated by small Bo-Bo locomotives, working on the low voltage of the Tyneside suburban lines, but overhead conductors have been installed owing to the difficulties of carrying out shunting operations where the third rail is laid down.

In 1914 the N.E.R. applied the 1,500-volt d.c. system to the Newport-Shildon mineral line, 18·5 miles in length, and over this section heavy mineral trains are hauled by double-bogie locomotives weighing 74 tons and having driving wheels of 4 ft. diameter. The same company had in contemplation a very ambitious electrification programme prior to its fusion in the L.N.E.R. in 1923, and this included the equipment of the entire main line between York and Newcastle, using 1,500-volt d.c. with overhead conductors and large high-speed electric locomotives, whereby all trains over that route would be electrically operated. A solitary experimental locomotive of the 2-Co-2 type with 6 ft. 8 in. wheels was built, and is interesting as being the only electric locomotive ever built for express passenger traffic by a British railway.

In 1908 the Midland Railway electrified the Lancaster-Morecambe-Heysham lines, following upon experiments between Morecambe and Heysham made in the early part of that year. The single-phase system was used, with 6,600 volts at 25 cycles, and a standard train consists of a motor-coach between two driving trailers. Two pantographs are mounted on the roof of a motor coach, except in the case of an experimental Westinghouse car which carries a single pantograph. This electric line remains isolated from any other electrified system, and thus no trouble has been experienced from the electrical "break of gauge" such as that with which the Southern Railway had to contend until 1929. Power is purchased from the Morecambe Corporation and converted at Heysham, but

Electric train on the Liverpool Overhead Railway

was originally obtained from a gas engine generator set at Heysham Dock.

The origin of the extensive Southern Railway electrified system was the old L.B. & S.C.R. single-phase South London line, electric operation on which was inaugurated in 1909. Overhead conductors were used for the 6,600 volt current, and after the 1923 amalgamation the Southern Railway extended the use of this system to Sutton and Coulsdon before finally scrapping it in 1929, in favour of a universal installation of the d.c. third-rail system at 650 volts, which was introduced by the London & South Western Railway in 1915 and applied to the Eastern Section lines in 1924-25 and onwards. Although the former South Eastern & Chatham Railway obtained powers for electrifying its suburban lines before the amalgamation, and intended to electrify all of its main lines, no section was actually opened to electric traction until 1926. Originally, the scheme had been to use direct current at 1,500 volts with a third rail, and electrification was to have been carried out in two sections, the first of which comprised the suburban lines, and the second the Gillingham, Tonbridge, Redhill, Dorking, and Caterham lines, including all the main routes to these places. Suburban services were to be worked by multiple-unit trains, and main-line passenger and goods services by locomotives.

The present electrified London suburban system of the L.M.S.R. had its beginnings on the London & North Western Railway, which carried out its electrification programme between 1914 and 1922, the system being uniform with that of the District and the Metropolitan. Electric running began from between Willesden and Earls Court, in 1914, and from Broad Street to Richmond in 1916. The system was completed in 1932 by the opening of the Barking-Upminster extension, which is operated by the London Passenger Transport Board's District line trains. Eventually electrification through to Southend would seem to be a reasonable probability. Power for the North Western section is generated by the company's station at Stonebridge Park, and for the Barking lines is purchased from the Central Electricity Board. Open motor and trailer coaches were universal at first, but the L.M.S.R. has introduced compartment stock on the Watford service within the last few years.

Driving compartment and vestibule ends of stock used on Liverpool-Southport lines, L.M.S.R.

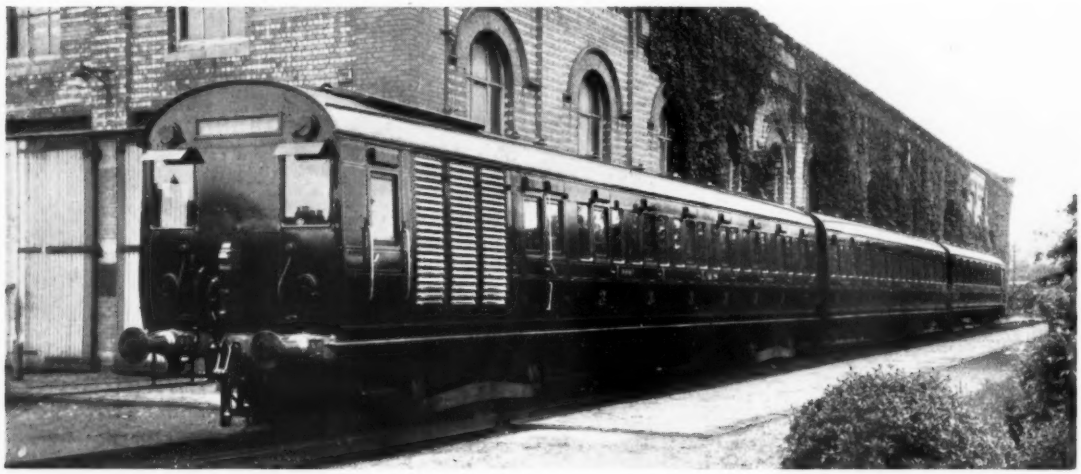
High-Voltage Passenger Line

The Manchester, South Junction & Altrincham Railway, owned jointly by the L.M.S.R. and L.N.E.R., forms the first instance of a passenger-carrying railway in this country electrified at 1,500 volts d.c. with overhead contact, as recommended by the Ministry of Transport Railway Electrification Committee of 1927. The electricity supply is obtained from the Grid, and is purchased by the railway from the Stretford Electricity Board, whose Longford Bridge substation transmits the current at 11 kV., 50 cycles, to the railway's substations at Old Trafford and Timperley. The line is operated by compartment trains, each normally containing a motor-coach and two trailers, these units being coupled together to form longer trains as required. The motor coaches have two 328 h.p. motors mounted on each bogie, and a single pantograph on the roof.

Train of Metropolitan stock alongside Piccadilly line train at Uxbridge station

LANCASHIRE ELECTRIFIED LINES OF THE L.M.S.R.

Up-to-date equipment has recently been installed in the substations of these pioneer electrified steam railways



Three-car train of compartment stock as used on the Liverpool-Southport line

THERE has always been a general doubt as to whether the Liverpool-Southport section of the L.M.S.R. or the Tyneside lines of the L.N.E.R. could lay claim to be the first electrified section of a trunk railway in Britain, and it appears as if the honour is due to the former—by a week. A partial service was brought into operation out of Liverpool by the Lancashire & Yorkshire Railway on March 22, 1904, whereas a public service was not inaugurated on Tyneside until March 29. By May 13 of the same year the whole of the passenger service between Liverpool and Southport was being worked electrically, two months before a full electric service was being run from Newcastle to the coast. The L.M.S.R. electrified lines in south Lancashire now comprise 50·9 route and 122·8 track miles in two distinct systems, the Liverpool-Southport and Manchester-Bury, plus the 8·75 route and 28·9 track miles of the Manchester, South Junction & Altrincham Railway, owned jointly with the L.N.E.R. Including the electrified suburban lines round London, most of which were converted under the direction of Lt.-Col. F. A. Cortez Leigh, the present Electrical Engineer of the L.M.S.R., and the Lancaster-Heysham line, the L.M.S.R. now has electrified route and track mileages of 104·2 and 244·0 respectively.

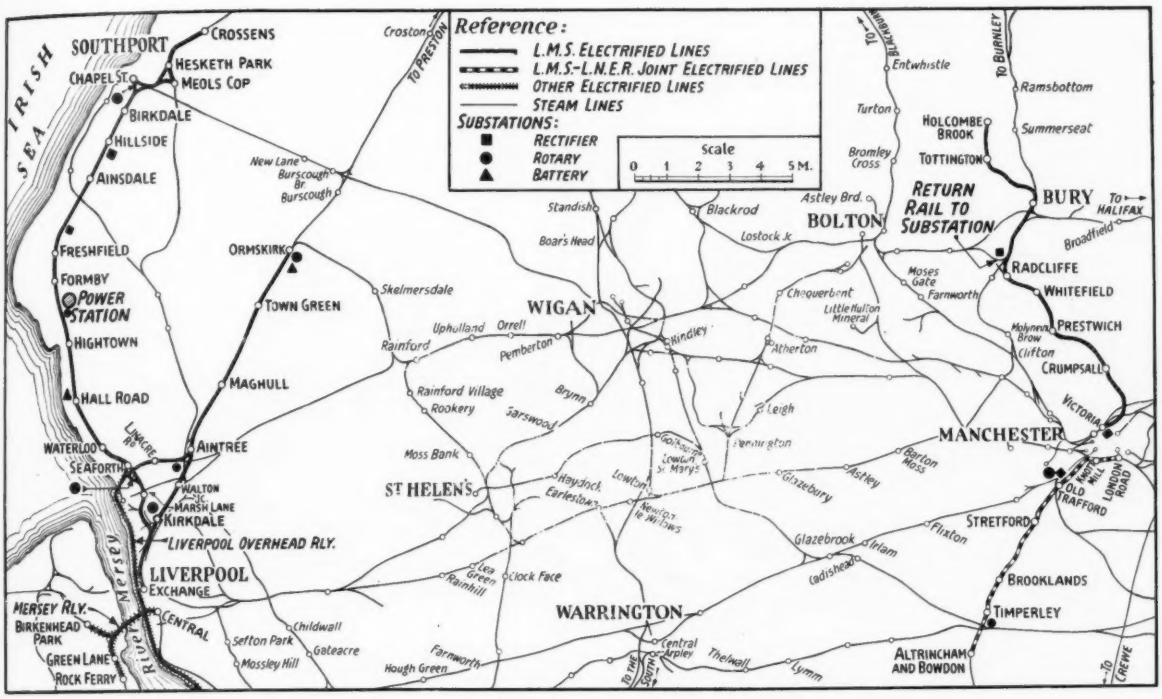
LIVERPOOL–SOUTHPORT DIVISION

The lines on which electric operation commenced in 1904 extended from Liverpool (Exchange) to Southport (Chapel Street), and from thence to Meols Cop and Crossens, but a separate train service has always been provided over the latter section, the trains from Liverpool terminating at Chapel Street. In July, 1906, the electrification of the branch from Marsh Lane to Aintree was completed, and in the same year electric trains commenced running to Aintree through Kirkdale. The extension to Ormskirk was not put in hand until 1912 and was opened in April, 1913, giving total route and track mileages of 37 and 94 respectively, the track figure including 7·0 miles of sidings. All of this mileage is operated by direct current at 600 volts with an outside third rail, and return through bonded running rails. From Liverpool to Seaforth the track is quadruple, and double over the remainder of the system, which includes only two short tunnels, both situated between Kirkdale and Walton junction. Seaforth station also forms the northern terminus of the Liverpool Overhead Railway, but the platform used by this line is distinct from those used by the Southport trains.

Power Supply and Transmission

In common with the majority of early British electrified lines, the Liverpool-Southport division was supplied with current from a power station of its own, which was erected by the L.Y.R. at Formby, near the mid-length of the line. The marshy nature of the ground made it necessary to build the station on what is virtually a raft of reinforced concrete, and the original equipment comprised four horizontal cross-compound 2,000 h.p. Yates & Thom steam engines coupled to 1,500 kW. Dick-Kerr three-phase generators. Steam was generated in 16 Lancashire boilers, which also supplied steam for a 700 kW. generating set with a vertical engine. Further additions were made in 1906 and 1912, but the increasing loads and higher efficiency of up-to-date plants caused a thorough modernisation of the equipment to be undertaken in 1922-24. The generating plant now consists of three 6,500 kW. turbo-generators built by the English Electric Company, and one 2,000 kW. Parsons geared turbo-generator which is used as a stand-by, giving a total capacity of 21,500 kW. The Lancashire boilers have been replaced by five Clayton-Shuttleworth water-tube boilers, each with an hourly evaporative capacity of 32,000 lb. at a pressure of 260 lb. per sq. in., the feed-water for which is de-aerated and passed through an evaporator.

The total number of units generated in 1933 was



Map of electrified railways in South Lancashire

44,016,900, of which 95 per cent. was for traction purposes. The peak loads occur from 8.0 to 9.0 a.m. and from 5.0 to 6.0 p.m., during which periods the average load for the whole hour is 11,700-11,900 kW. From the power station the 7,500-volt 25-cycle current is transmitted to the south by two three-phase overhead feeders of 0·15 sq. in. section and one lead-covered cable of 0·30 sq. in. section, and to the north by two three-phase overhead feeders of 0·15 sq. in. section.

Substations

The complete Liverpool-Southport-Crossens-Ormskirk division is fed by nine substations of three different types, which are located as shown on the accompanying map and detailed on the table on page 610. The original substations were at Formby, Seaforth, Bankhall and Aintree, and all were fitted with rotary machines, but in 1905 large battery stations were installed at Southport, Freshfield, Hall Road, and Liverpool, to act as standbys in case of a power-house failure and to reduce the fluctuations in the power-station load. These battery stations have now been dismantled, except that at Hall Road, but some of the accumulators have been transferred to Ormskirk, which substation also includes rotary converters. A general scheme of reconstruction of the substations, feeders, and rolling stock has been under consideration for some time, and the first part of this work was undertaken when the old air-blast transformers were replaced by oil-cooled units, some of the substation switchgear replaced, and two new mercury-arc rectifier substations installed. The first of these substations was erected at Wicky Dale in December, 1932, and the second at Hillside in April, 1933. Both are remotely-controlled from Southport. The old rotary machinery from Hillside was transferred to Southport substation in place of the battery, and Hall Road and Ormskirk are now the only substations with batteries.

These rectifiers were the first of the glass-bulb type to be employed for railway traction in Britain, and were designed and manufactured by the Hewittic Electric Co. Ltd. to the requirements of Lt.-Col. F. A. Cortez Leigh. They are of the same type as those in the two substations of the Manchester-Bury line, described later. Wicky Dale and Hillside substations each contain an eight-bulb rectifier bank with a normal capacity

General view of Formby power station, L.M.S.R.

of 1,200 kW., but capable of giving 4,000 amp. for ten minutes. Should any circuit-breaker trip in these two substations, a bell rings in Southport rotary station, and the operator there re-sets them electrically. The rectifier breakers are operated by solenoids, and the remainder by small electric motors. The high-tension switchgear is of Reyrolle manufacture, and is arranged for use in conjunction with the low-tension d.c. switchgear and remote-control apparatus supplied by Bertram Thomas Limited, of Hulme, Manchester. Each substation has a three-panel e.h.t. switchboard, consisting of two incoming feeder panels and a transformer panel. From the feeder line the current is passed through static transformers and is led to the rectifiers as 12-phase 50-cycle a.c., emerging as d.c. at 600 volts. Top-contact third rails with a weight of 105 lb. per yd. are now being laid in 60-ft. lengths, and replace the old 70 lb. per yd. rails. As a result of the provision of additional substations and a heavier conductor rail, the voltage drop has been reduced.

Rolling Stock

It is difficult to say what is a normal train on the Liverpool-Southport section, for anything from three to six-car units are run, and in addition there is a separate service of parcels vans, which run singly. In general, the vestibuled coaches are 60 ft. long, with an overall width of 10 ft., and they were designed for use only over this particular electrified section. The rolling stock comprises 85 motor-coaches, 17 driving trailers, 98 trailers and 3 parcels vans, the motor-coach total including 11 of the short cars used on the Southport-Crossens service, where every vehicle is a motor-coach. The most recent stock consists of 11 motor-coaches, with Metro-Vick motors and B.T.H. control gear, 11 driving trailers, and 12 trailers, which were built in 1926. The motors are designed to give 265 h.p. at 530 volts, which rating allows of adequate power with a nominal drop in the line voltage. These vehicles are of the compartment type, 9 ft. wide, and are similar in outside appearance to the Watford stock described in the issue of this Supplement for October 27 last. They are shown in the illustration at the head of this article.

Substations on Liverpool-Southport Division

Bank Hall ..	Rotary converters ..	3,600 kW.
Seaforth	,, ,, ..	3,600 kW.
Hall Road ..	Battery	1,200 amp. hr.
Formby	Rotary converters ..	2,400 kW.
Wicky Dale ..	Rectifiers	1,200 kW.
Hillside	,, ...	1,200 kW.
Southport	Rotary converters ..	2,400 kW.
Aintree	,, ,, ..	1,800 kW.
Ormskirk	,, ,, ..	600 kW.
	Battery	1,300 amp. hr.

Vestibules are fitted to the ends of all the open-type coaches, and the seats are arranged transversely with a centre gangway. Doors are arranged at the ends only, and when the train is ready to start the guard turns a key in the end coach and this operates a bell in the motorman's compartment. The bodies are of wood, with straight sides, and thus differ from the all-metal stock of the Manchester-Bury trains.

Train Services

Commencing at 5.10 a.m., there is a service of 106 passenger trains each way per normal week-day over the Liverpool-Southport line, 65 on the Liverpool-Ormskirk section, and 18 from Liverpool to Aintree via Linacre

Approach to Exchange station, Liverpool, showing electrified lines

Five-car vestibule train on Liverpool-Southport service

Road. On all lines there are also steam-operated goods services, mainly at night, and the Ormskirk line has about a dozen steam-hauled expresses in each direction daily and the Southport line a number of electric parcels services. The ordinary trains to Southport are booked over the 18½ miles in 45 min., including 14 stops, but the fastest train does the distance in 28 min. inclusive of one stop. The week-day service to Crossens consists of 46 trains in one direction and 47 in the other, and the journey of 3·3 miles, with four intermediate stops, is covered in 13 min. During 1933 the electric train miles run on the Liverpool-Southport electrified division of the L.M.S.R. amounted to 1,896,939.

MANCHESTER-BURY DIVISION

The avowed policy of the Lancashire & Yorkshire Railway in electrifying the suburban line from Manchester (Victoria) to Prestwich and Bury was not to save money but to gain traffic, and when the work of conversion was put in hand about the beginning of the war, ten years' proof of this pudding was to be found in the success of the electrified lines in the Liverpool area.

In 1913 the L.Y.R. carried out an experimental electrification of the 3¾-mile branch line from Bury (Bolton Street) to Holcombe Brook, using direct current at a tension of 3,500 volts and overhead construction for the contact line. Although trouble was experienced with insulators and surges in the line, the working of this branch indicated that a higher voltage than that used on the Liverpool-Southport section would be beneficial, and when the Manchester-Bury conversion was sanctioned it was decided to employ a line pressure of 1,200 volts, this being the maximum value allowed by the Board of Trade for third-rail systems. To give additional protection, the third-rail adopted was of the side-contact type in 60-ft. lengths weighing 85 lb. per yd., and practically all the original conductor rails are still in use after 19 years' service. Running rail return is used, and a fourth rail, laid between the running rails, provides additional conductivity.

Electric operation over the 9·95 route miles from Victoria to Bolton Street station, Bury, was commenced in April, 1915, and the Holcombe Brook line was shortly afterwards converted to 1,200 volts with protected third rail, giving a total electrified route mileage of 13·76 and a track mileage of 28·25, including 2·78 miles of sidings. There were originally six stations between Manchester and Bury, and seven stations or halts between Bury and Holcombe Brook, but last year a new station, Besses o' the Barn, was opened between Prestwich and Whitefield. On the first division the minimum distance between stations is 0·58 miles and the maximum 2·27 miles, but on the second division the spacing is more even, varying only from 0·38 to 0·66 miles.

Power Supply and Transmission

As with the Southport line, the Lancashire & Yorkshire Railway decided to generate the current for the Manchester-Bury line in a power station of its own, and this was laid down at Clifton, on the main steam line to Bolton, and 1½ miles away from the nearest point of the electrified system. This station had a capacity of 10,000 kW., but when a few years ago it became necessary to consider the installation of new machinery, it was decided that current could be more cheaply purchased outside, and the station was gradually closed down, the load being transferred to the Outwood generating station of the Lancashire Electric Power Company. Current is supplied direct to both substations.

The maximum demand from the power company is approximately 5,000 kW. per hour. Clifton station having generated and transmitted three-phase current at 6,600 volts 25 cycles, it was necessary to instal new substation plant when changing over, as the current transmitted from Outwood is three-phase 11,000 volts 50 cycles.

Substations

Due to the relatively high contact line voltage, only two substations are employed, and although they are not situated equidistantly along the complete line, they are close to the electrical " centre of gravity " of the system. Originally the equipment of both the Radcliffe and Victoria substations consisted of three 1,000 kW. rotary converters and a battery, with a fourth set added later, but conversion is now carried out entirely by rectifiers, which have given exceptionally reliable operation for over twelve months.

At Radcliffe, current is led from the transmission line through Ferranti surge absorbers, thence through high-tension switchgear, manufactured by Switchgear & Cowans Limited, which has a rupturing capacity of 350,000 kVA., to Hackbridge static transformers which produce 12-phase current at 1,385 volts on the secondary side. This is led to the a.c. side of the rectifiers. The switchgear is manually-operated, and the incoming feeders are fitted with balanced power protection. The rectifier switches have time-limit overload and earth leakage protection, and each feeder has its own watt-hour meter. The busbars are divided by an oil-immersed section switch placed

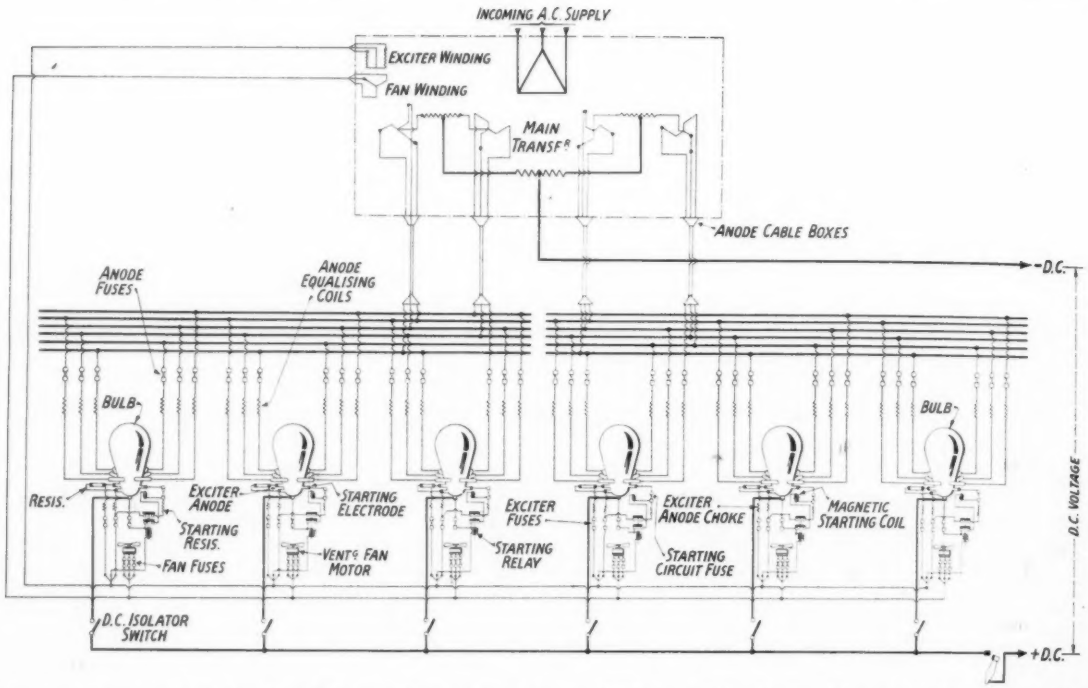


Diagram of connections for glass-bulb rectifiers as used in Radcliffe and Manchester (Victoria) substations, L.M.S.R.

between the incoming feeders, and a circuit for the station lighting and auxiliaries is taken off the bus bars through a 350,000 kVA. oil-switch fuse. The mounting of the h.t. switchgear is shown in one of the accompanying illustrations.

Glass-Bulb Rectifiers

The glass-bulb rectifiers, which form the principal feature of both Radcliffe and Victoria substations, are of the type developed by the Hewittic Electric Co. Ltd. at their Walton-on-Thames works. The rectifier units are identical with those installed in the Wicky Dale and Hillside substations on the Liverpool-Southport division, but owing to the higher line voltage of the Manchester-Bury line, the 1,200 kW. rectifier banks at Radcliffe and Victoria each comprise only six bulbs, in place of eight, each bulb having a rated output of 200 kW. Both substations have three rectifier banks, giving a total substation capacity for the line of 7,200 kW. Each bank has a normal capacity of 1,000 amp. at 1,200-1,500 volts, but is capable of giving 1,250 amp. for two hours, 2,000 amp. for ten minutes, and 3,000 amp. for short periods. This flexibility in operation, coupled with the reliability and simplicity of operation and control, is ideal for electric traction. Victoria substation is unattended, and remotely controlled from Radcliffe.

One-half of a 1,000 amp. rectifier bank as installed at Radcliffe is shown, with doors off, in an accompanying illustration. The full rectifier unit consists of six main bulbs and their auxiliary gear enclosed in a steel sheet and grilled cubicle, the door of which is interlocked with the e.h.t. and d.c. switchgear so that access cannot be gained to the rectifier unless the apparatus is dead. Each anode is fitted with a quick-acting fuse, and there is an isolating link controlling the output from each cathode, which together permit of separate protection and isolation for each bulb. Starting and exciting circuits for each bulb are used, and the cooling fan is driven automatically at a speed proportional to the load on the bulb. An auxiliary winding on the static transformer supplies current for the fan motor and the exciting anodes.

In the accompanying illustration of the three-bulb half, the a.c. bus-bars may be seen at the top of the cubicle, and the positive d.c. bus-bars at the bottom. A diagram of the rectifier connections at Radcliffe substation is given with this article, and it will be seen therefrom that three units are connected to each set of bars. The 12-phase secondary current of the transformers is taken to two sets of six-phase bus-bars, each rectifier thus operating as a six-phase unit, any number of which can be connected in parallel to each group of bars.

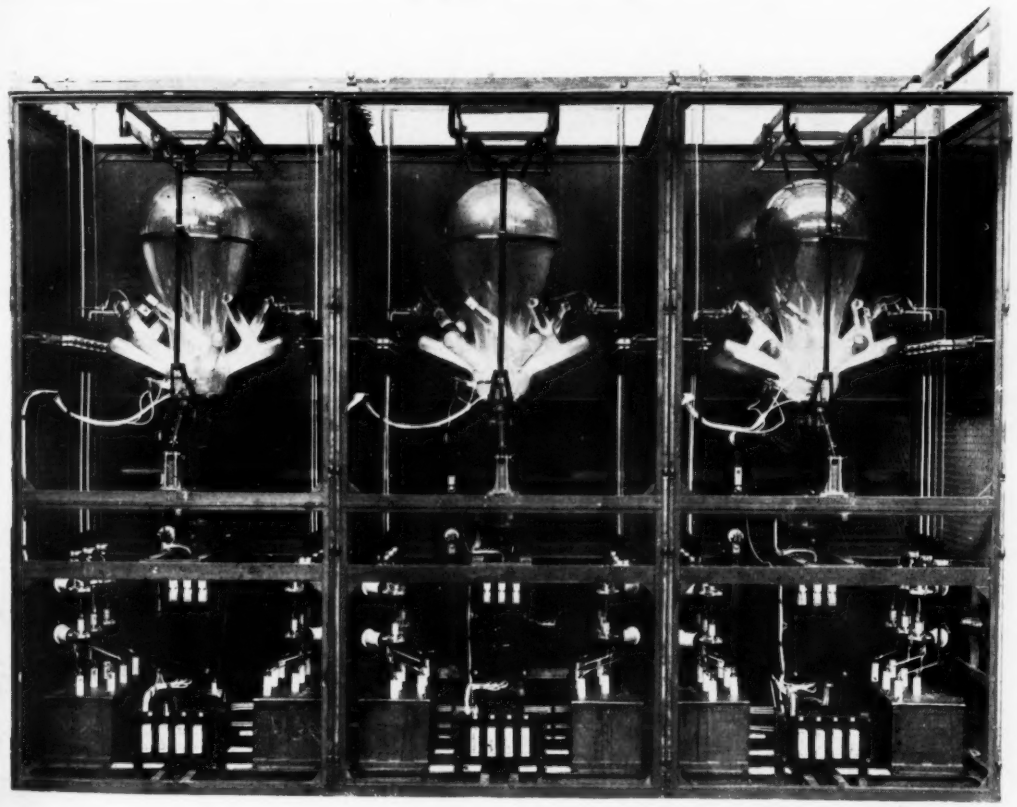
When the rectifiers were being installed at the beginning of last year, no interruption of traffic could be countenanced, and the rectifier banks were therefore erected and coupled up gradually as the rotary machines were taken out, but the power supply during this change-over period was double (6,600 volts 25 cycles for the rotaries and 11,000 volts 50 cycles for the rectifiers), and two rectifiers were worked in parallel from the 50-cycle supply and two rotaries in parallel from the 25-cycle supply until the third rectifier was in position. From first to last the transition period covered eight weeks. The rectifiers at Victoria are duplicates of those at Radcliffe, except that the former have bulb-alarm circuits which operate a bell at Radcliffe should any bulb cease to function. The rupturing capacity of the switchgear at Victoria is only 150,000 kVA., as it is seven miles away from the power station.

Remote-Control Apparatus

For operating the Victoria substation from Radcliffe the Evershed-Midworth distant-repeater control, manufactured by Evershed & Vignoles Limited, has been adopted, and the controlling panel at Radcliffe, located between the h.t. switchgear and the cubicles containing the outgoing track-feeder switchgear and the rectifier meters, can be seen in one of the illustrations presented herewith. This control apparatus not only enables the Radcliffe attendant to start and stop any rectifier set at Victoria, but also open or close

the switches that connect them to the track, and operate the circuit breakers.

The whole control is arranged through four pilot lines between the two substations. The operations to be carried out at Victoria are first selected by means of the control transmitter at Radcliffe, as shown on the meter scale or diagram, and actual operation is then carried out through push buttons. Confirming signals are received showing that the desired operation has been correctly performed. After any operation, the lock switch is turned to "free," the control transmitter set to normal, and the lock switch returned to the lock position, and in this position the equipment is ready to receive the indications



Half of 1,200 *kW. six-bulb rectifier set, L.M.S.R.*

and give alarm in the event of any circuit breaker tripping. No fewer than 22 operations at Victoria may be carried out by remote control from Radcliffe, these comprising the opening and closing of two extra high-tension and three transformer oil switches, and the same operations on three rectifier and three track-feeder circuit breakers. On the panel at Radcliffe, 28 indications can be received, comprising the d.c. load on each of the three rectifier banks, 11 switch positions, and 14 alarms for switch tripping and bulb failures. A circuit-breaker trip at Victoria not only causes an alarm bell to ring at Radcliffe, but also gives an indication by means of three lamps on the diagram at that station, as to which particular group of breakers contains the one which has tripped out.

Rolling Stock

One of the most interesting features of the original Manchester-Bury electrification was that the rolling stock was of all-metal construction, probably the first of this type on a main-line railway in Britain. The framework and doors were of steel and the roof and the panelling of the sides and numerous brackets were of aluminium. The cars were constructed at the Newton Heath shops of the L.Y.R., and are made up into trains of three, four, or five vehicles as traffic requires. All trailers are of the driving type, and a driving cabin is provided at both ends of all cars, so that trains of any required formation may be made up with the minimum of shunting. A five-car train, comprising three motor-coaches and two trailers, has a seating capacity of 72 first-class and 317 third-class, in a length of 326 ft. 3 in. and a tare weight of 220 tons. The stock is of the vestibuled open type with end doors.

Each motor-coach has four nose-suspended motors of 200 h.p. giving a total capacity for a five-car train of 2,400 h.p. At the time of their inception, these motors formed a distinct advance in British electric traction practice, for they are wound for 1,200 volts. The original motors are still in use, and although some of the armature shafts are now being replaced, the single-brush commutators are those put in during 1915-16. The spur gearing has a ratio of 2·36 to one, and the gear wheels and pinions have an average life of approximately 150,000 miles.

Train Service

The rolling stock now comprises 38 motor-coaches, 14 first-class driving trailers and 14 third-class driving trailers, which maintain a week-day service of 82 trains in each direction on the Manchester-Bury line, and 29 between Bury and Holcombe Brook. No trains run right through from Victoria to Holcombe Brook, and a

Above: D.C. switchgear, remote-control panel, and h.t. switchgear. Radcliffe substation
Left: Remote-control panel. Victoria substation

change must be made at Bolton Street station, Bury. The time taken over the 9·95 miles from Victoria to Bury with seven intermediate stops is 24 min., and over the 3·81 miles on to Holcombe Brook with five intermediate stops, 14 mins. During 1933 the electric train mileage was 627,758, giving a density per mile similar to that obtained on the Liverpool-Southport division.

CONCLUSION

Details of the L.M.S.R. joint line in south Lancashire, the Manchester, South Junction & Altrincham Railway, need no recapitulation here, as they were fully described in the pages of THE RAILWAY GAZETTE at the time of the conversion in 1931. The following table, however, gives brief particulars of this line in comparison with equivalent 1933 figures for the Liverpool-Southport and Manchester-Bury lines, and forms an interesting sidelight on the characteristics of these three suburban systems.

	L.-S.	M-B.	M.S.J.A.
Voltage	6.0	1,200	1,500
Route mileage	37·0	13·76	8·7
Track mileage	94·0	28·25	28·9
No. of vehicles in rolling stock list	204	66	68
Electric train miles per annum	1,896,939	627,758	522,900
Total current consumption per annum kWh.	44,016,900	11,219,950	11,652,010

Electric motor-coach as used on Manchester, South Junction & Altrincham Railway

The Liverpool-Southport and Manchester-Bury electrification schemes were carried out by the Lancashire & Yorkshire Railway under the direction of Sir John Aspinall, the General Manager. The M.S.J.A. Railway was electrified by the L.M.S.R. under the direction of the Electrical Engineer, Lt.-Col. F. A. Cortez Leigh, in consultation with Mr. H. N. Gresley, Chief Mechanical Engineer of the L.N.E.R. To Lt.-Col. Cortez Leigh our thanks are due for the many facilities placed at our disposal for inspecting the above lines and observing the behaviour of the substation plant and rolling stock in operation.

The remaining L.M.S.R. electrified line in Lancashire, between Lancaster and Heysham, is isolated from all other electric systems. It is briefly referred to in the article, "The Development of Electric Traction in Britain," in another part of this issue.

THE TYNESIDE ELECTRIFIED AREA OF THE L.N.E.R.

Favourable results obtained over a period of 30 years

The first electric train at Newcastle-on-Tyne. 1904

THE decision to electrify the north Tynside suburban lines in 1904 was made at a time when the North Eastern Railway had lost nearly a third of its passengers in this area by the electrification of the municipal tramways and the opening of a through route for such trams from Gosforth to North Shields. Those who left the railway were the short-distance passengers, and the management realised that it was the function of tramways to carry those people, since they could traverse the main streets of the city and the routes of habitation in the nearer suburbs, but in order to safeguard and encourage the longer distance traffic, a programme of faster and more frequent trains running at regular intervals was drawn up, and as the anticipated density of traffic was above that with which steam traction could cope economically, there was no alternative but electric traction.

Contracts for the conversion work were signed in 1903 with the British Thomson-Houston and British Westinghouse Companies, and in September of that year experimental running began between Carville and Percy Main. The lines electrified consisted of the Newcastle (Central)-Wallsend-Tynemouth-Backworth-Gosforth-Newcastle (New Bridge Street) route, with a loop from near Heaton along the river bank to Percy Main, and a portion of the Newcastle-Berwick main line between Newcastle, Heaton and Benton. It was originally intended to electrify the branch line north-west from Gosforth to Ponteland, but this was never carried out, and the branch is now closed to passenger traffic.

Actually, the Tyneside lines were the first section of a trunk railway in Britain to be operated by electric traction, for an electric service between New Bridge Street station, Newcastle, and Benton was begun on March 29, 1904, a week after a partial service was inaugurated on the Liverpool-Southport electrified line of the L.M.S.R. (then Lancashire and Yorkshire Railway). The complete Tyneside electrification scheme, as far as the suburban lines were concerned, was finished by the end of July, 1904, when there was a daily service of 195 trains at intervals of approximately a quarter of an hour, replacing 121 steam trains which had run at irregular times.

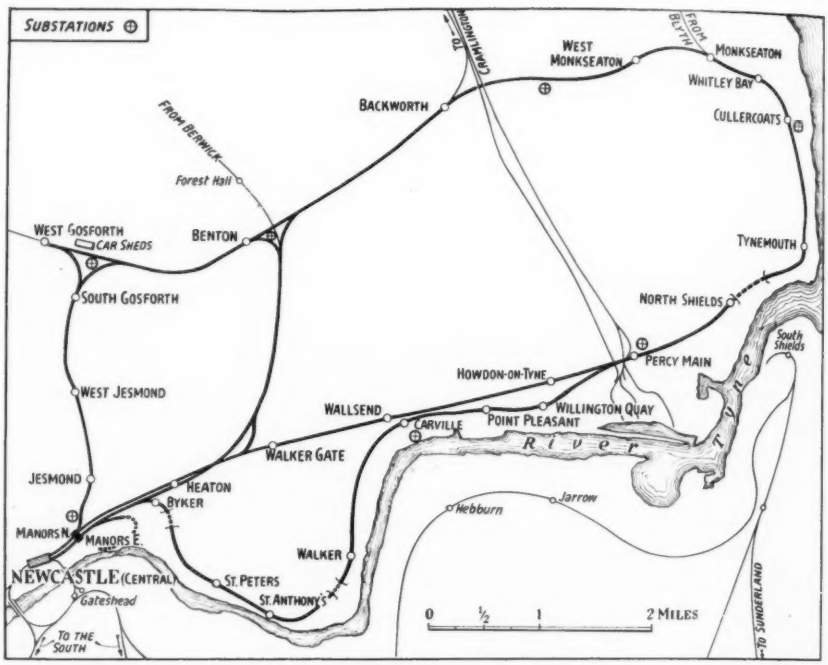
In June, 1905, electric operation was commenced on the goods line, with a grade of 1 in 27, between Manors East and the Quayside, but although direct current at 600 volts tension was used, as in the suburban area, overhead contact wires were adopted in view of the line traversing the quays. The total electrified route mileage is now 31·8, and the track mileage 80·4, including 12·2 miles of sidings. The train-miles per annum in 1930 were 1,057,263, and the maximum hourly train-mileage occurs between 5.0 and 6.0 p.m., when the figure averages 195·5. The gross ton-miles per running track-mile per annum approximate to 2,000,000, and the traffic density is thus just about up to what is usually considered an economical figure for electrification.

In the first years of the present century it was usual for railway companies embarking upon electrification schemes to construct their own power station, but the North Eastern was an exception, as from the beginning it purchased its supply from the Newcastle-upon-Tyne Electric Supply Company, which company, in consequence, was considerably assisted in the development of its undertaking. The system of transmission is by underground cables to, originally, five substations, but the number of the latter has just been increased to seven by the construction of the Gosforth East and Earsdon Grange substations. The Gosforth station is now in operation, remotely-controlled from Benton, and that at Earsdon is to be opened within the next few months. All the substations are of the rotary converter type with machines of 1,000 kW. capacity. Pandon and Cullercoats have three machines each, Gosforth East and Earsdon Grange one, and the remainder two each, the total substation capacity thus being 14,000 kW. Three-phase current at 5,750 volts 50 cycles is received through Metro-Vick transformers, except at Earsdon Grange, where the voltage is 20,000, and is

converted to d.c. with a tension at the low tension busbars of 630 volts. Some of the substations, at the moment of writing, are still operating on the old 6,000-volt 40-cycle supply.

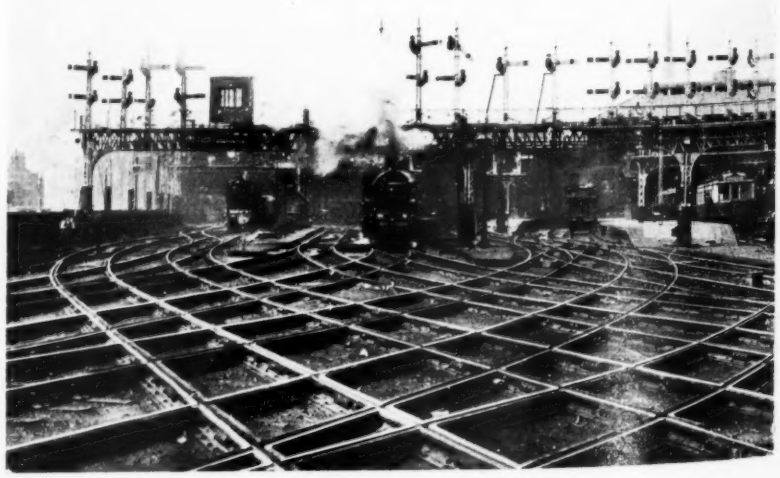
For the original service, 125 vehicles were built at a cost of £235,000, and to form a departure from the then standard N.E.R. crimson lake, this stock was painted red and cream. The cars are of the open type with large, deep windows, and within a length of 55 ft. seat 68 people in a motor-coach and 70 in a trailer. The normal mid-day train consists of two motor-coaches and a trailer, and during rush hours two of these sets are coupled together. Eight-car trains, consisting of four motor cars and four trailers, are also run in peak periods. Two 150 h.p. motors per motor-coach are used, giving a total h.p. of 1,200 for a six-car train. On August 11, 1918, a serious fire at the Walker Gate car sheds caused the loss of 19 motor-coaches and 15 trailers, but by the end of 1922 these had been replaced by a similar number of modern vehicles, and a motor parcels van, the last-named being fitted with four motors to enable it to work heavy milk and fish traffic. There is now a total of four motor parcels vans on the Tyneside system. The only other examples of this practice are to be found on the Liverpool-Southport section of the L.M.S.R., but the L.N.E.R. goes further than that line, for a six-coach train of compartment stock is fitted up with power and control train lines, and in an emergency, or with an exceptional rush of traffic, can be hauled by two of the motor vans.

The rolling stock now comprises 67 motor-coaches, 55 trailers, 4 luggage-vans, and the six-car compartment train; and these maintain a passenger service of 227 trains per normal week day and 214 trains on Saturdays. Two electric locomotives are used for the Quayside service. In 1910, New Bridge Street station, which was a terminus, was dismantled, and an extension made to Manors station, which was then divided into two interconnected portions known as Manors East and Manors North. A short length of new line from New Bridge Street to Manors enabled trains to run to and from the Central station in both directions. In order to cope with the increasing residential traffic from the coast, a new station, named West Monkseaton, was opened last year, and provides excellent travel facilities for a rapidly-developing district. Within the three decades of electric traction, Whitley Bay and Monkseaton have trebled their population, while that of the remaining portion of the electrified area has increased by over 50 per cent.



Map of Tyneside electrified lines

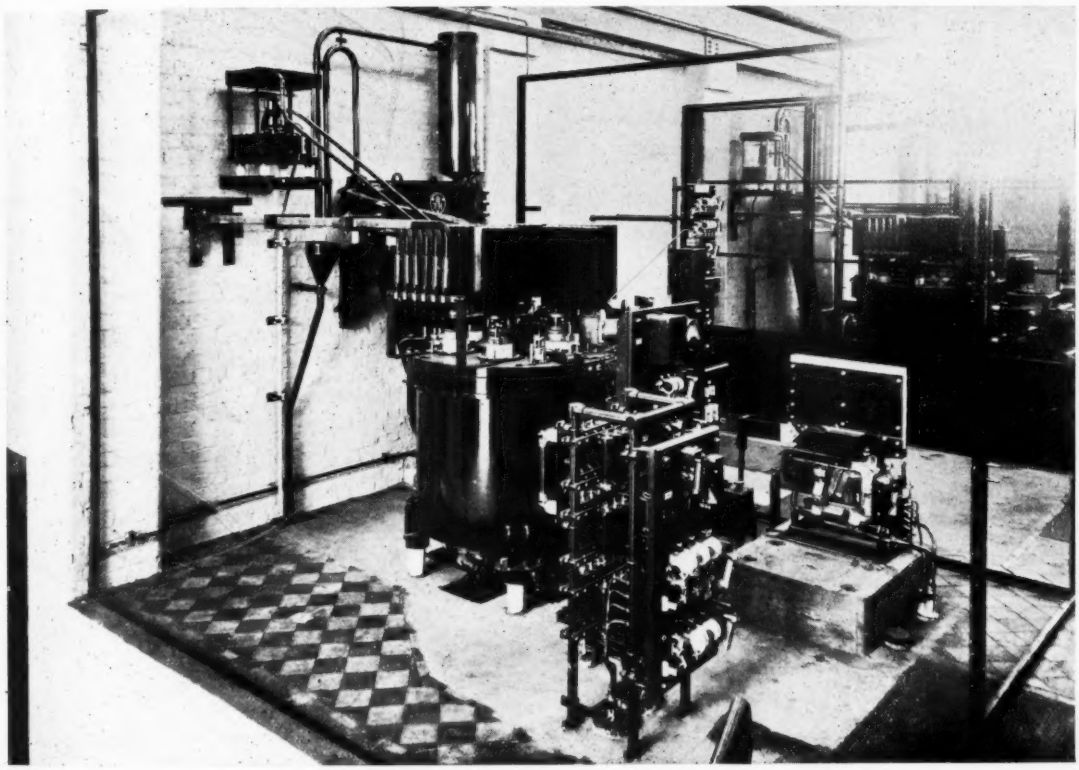
To allow a greater freedom of movement, the two northernmost lines of the quadruple track from the Central station to Heaton are now being signalled for either way working. A recent innovation is the decoration of the stations in brighter colours, and each station is distinguished by separate and distinctive colours, but with a base of green and cream. Following the practice introduced by Mr. John Miller, Engineer of the North Eastern Section, the ballast is neatly kept, and every spare piece of ground planted with neat grass plots.—P.A.H.



Crossing at east end of Newcastle Central station; the electric trains use the three platforms on the right

MODERNISATION OF NEWPORT-SHILDON LINE

L.N.E.R. instals metal-clad rectifiers in a substation on a heavy mineral traffic line



General view of metal-clad rectifier plant in Erimus substation, L.N.E.R.

AN interesting application of mercury-arc rectifiers to railway traction service in this country is to be found on the Newport-Shildon mineral line of the L.N.E.R., in one of the two substations of which British Thomson-Houston steel tank rectifiers were installed in December, 1932. The line in question was the first in Britain to be electrified at 1,500 volts d.c., and was put into operation in 1914. Conversion work over a route mileage of 18·5 and a track mileage of 48·3 was undertaken, and the line is almost consistently downhill in favour of the heaviest load, which consists of mineral trains from the Bishop Auckland district to the ironworks of Cleveland.

Two substations, located respectively at Middlesbrough (Erimus) and Aycliffe, convert the high-tension transmission current to the contact line voltage. Originally, the high-tension supply was three-phase 11,000 volts 40 cycles at Erimus, and 20,000 volts at Aycliffe and was passed through B.T.H. rotary converters. At Erimus there were one 800 and one 1,200 kW. machines, and at Aycliffe two 200 kW. converters, and the two 750-volt machines in each substation operated in series to give 1,500 volts. Due to the change-over in frequency from 40 to 50 cycles, consequent upon the supply being linked up with the Grid, new substation plant became necessary, and with a view to obtaining efficient, reliable, and economical operation, the opportunity was taken to instal rectifiers in one of the stations. The main transformers are installed in cubicles adjacent to the rectifier room, and taped copper connections are taken through the dividing wall from the transformer secondary to the rectifier anode terminals, which are supplied with six-phase current.

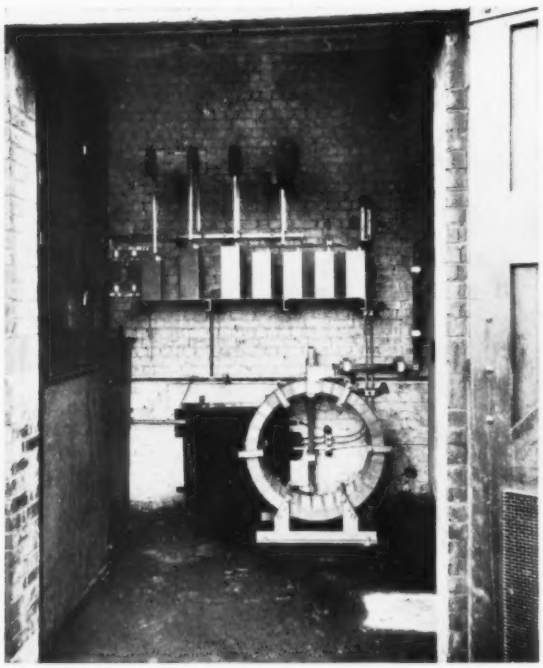
Erimus substation is now equipped with two rectifiers, one of 1,200 kW. and the other of 800 kW. rated capacity, and a general view of this plant (with the screens round the unit in the foreground removed), is shown in the first of the accompanying illustrations. Aycliffe substation is to be similarly equipped in the near future. Each unit can withstand an overload of 50 per cent. for two hours, 100 per cent. for ten minutes, and 200 per cent. momentarily. The rated load for the 800 kW. set is 533 amp. and for the larger unit, 800 amp. The plant is arranged for manual control, and the sequence of operations to start a unit is to close the switch for the ignition and excitation of the rectifier, and then close the main high-tension oil switch, after which the rectifier high-speed circuit breaker closes automatically to connect the plant to the d.c. bus-bars. Remote control is not embodied at the moment, but the plant has been designed

in such a manner that its provision at a later date will not necessitate modification of the existing switch gear.

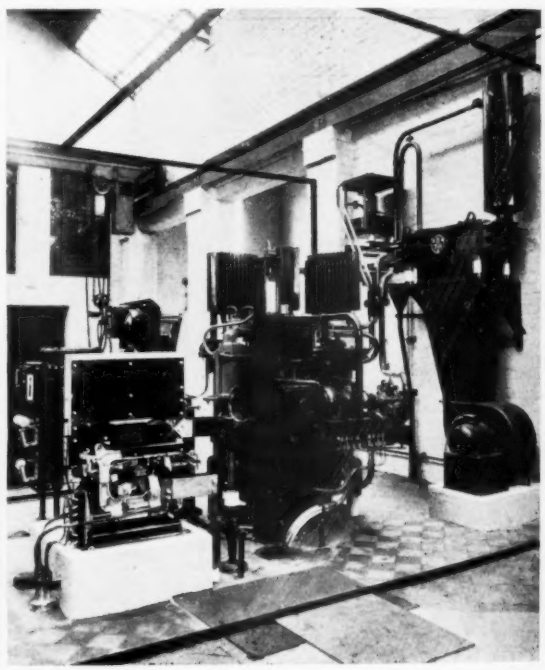
Protection for the plant is provided by a.c. overload and earth leakage relays on the high-tension side, a reverse tripping high-speed breaker in the d.c. positive connection to the bus-bars, excess temperature thermostats on the rectifier, and fuses and thermal overload relays in the auxiliary circuits. Each rectifier unit includes a smoothing circuit, which comprises a d.c. air-core self-cooled reactor coupled to the main negative connection to the transformer neutral, and a series of resonant shunts and condensers tuned to the frequencies of the principal harmonics in the d.c. voltage, and connected across the d.c. system. A view of this equipment is given in the second of the illustrations presented with this article.

A separate closed-circuit cooling system is fitted to each rectifier, and consists of a main recooler with a motor-driven fan for the cooling of the rectifier itself, and a small auxiliary recooler with a combined motor-driven fan and pump for the mercury vapour vacuum pump, which appartus may be picked out in the background of the third illustration. The fan motor for the main recooler is thermostatically controlled, so that the maximum economy of power consumption for the apparatus is obtained, and the temperature of the rectifier kept at its most suitable operating value. Circuits for the control gear and rectifier auxiliaries are supplied with current from an auxiliary transformer, the high-tension supply to which is controlled by a manually-operated oil circuit-breaker equipped with overload trips. Fuses are provided on the low-tension side.

One of the advantages derived from the installation of rectifiers is the high efficiency of the plant at all outputs from " running light " to heavy overload, and this gives a high efficiency throughout the day, even with a low load factor. On test, one of these Shildon-Newport 1,200 kW. rectifiers showed an efficiency of 96·56 per cent. at three-quarter load and 96·42 at full load, in both cases without the smoothing circuit or recooler blower motor in operation. These values may be taken as representative of the efficiency of rectifiers over a wide range of sizes.



View of smoothing circuit equipment for metal-clad rectifier



View of closed circuit cooling equipment for metal-clad rectifier

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SOUTHERN RAILWAY EXTENSION.—The conversion work on the Bickley-Swanley-Sevenoaks section is progressing favourably, and it is understood that electric operation from Bickley to St. Mary Cray will commence on May 1. At this rate it is not unreasonable to anticipate that the line from St. Mary Cray to Sevenoaks and the main line from Orpington to Sevenoaks will be electrified by the end of this year, and that the Hastings and Eastbourne extensions will be opened to electric traction by the summer of 1935.

ELECTRIFICATION BILL.—The Government has introduced into the House of Lords a Bill to simplify the purchase of electricity by railways contemplating extensive electrification schemes. At the present time railways must negotiate with various supply companies along the route for the supply of power, and this may lead to a number of separate agreements at varying rates. The existing powers of the Central Electricity Board only allow it to generate electricity for distribution to retail supply companies, but the new Bill seeks to make an exception in the case of railways, so that one agreement can be drawn up for the purchase of current for railway traction.

SPANISH ELECTRIFICATION.—All the tenders for the conversion of the main line of the Northern Railway of Spain between Madrid and Avila, and the old main line between Villalba and Segovia, have now been received. It is now proposed to connect the Northern Railway with the Southern Railway by boring a five-kilometre tunnel under Madrid, and this will also enable suburban traffic to be brought right into the centre of the capital.